10^3 Segment MEMS Deformable-Mirror Process Development

NASA Phase I SBIR - NNX09CE01P

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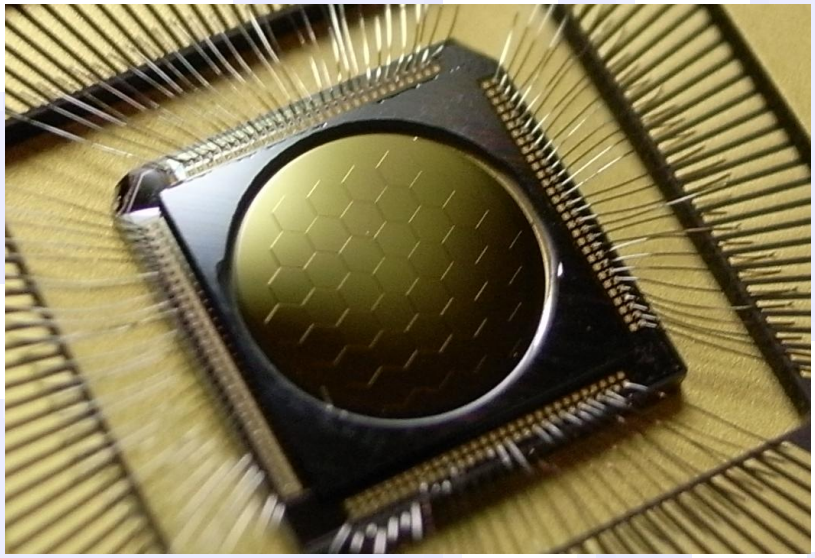
9th Annual Mirror Technology Days

June 16th – 18th, 2009

Precision DMs & Electronics

Compact



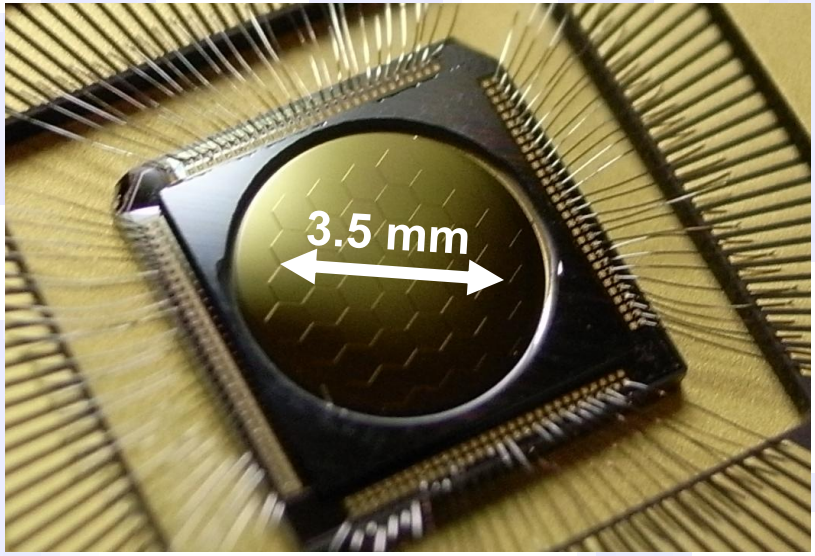
Robust

Easy to Use

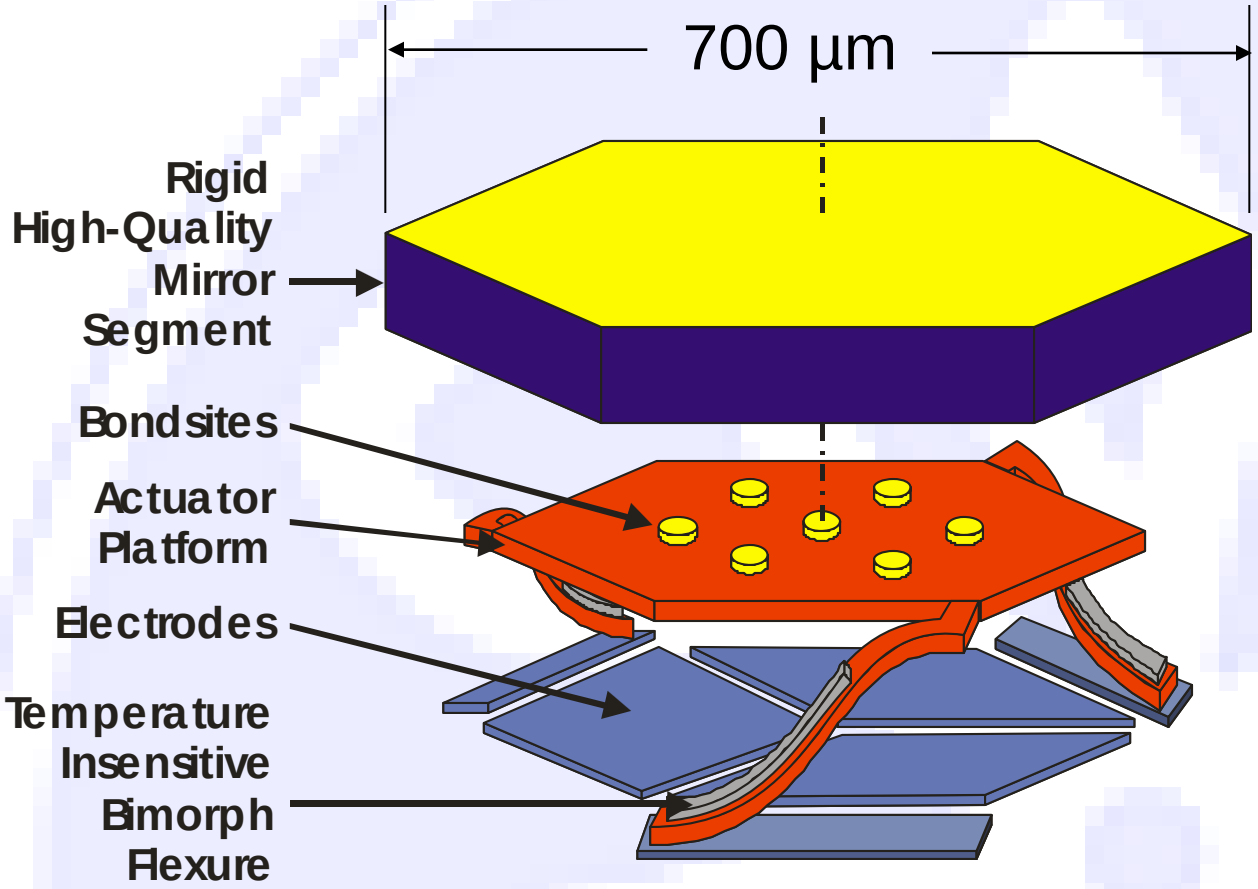
Outline

- Iris AO Segmented DM Background
- DM Scaling Development
- NASA Phase I SBIR Progress
- (Some of the) Challenges for 10^3 segments

S37-X: *A solid foundation*



Segmented MEMS DM Schematic



- Robust single-crystal-silicon assembled mirror surface stays flat (0.56 nm/°C PV)
  - Enables protected silver and dielectric coatings
- Temperature-insensitive bimorphs elevate mirror above substrate (14 nm/°C, σ=0.8 nm/°C)
- Piston/tip/tilt electrostatic actuation
- 2.3 kHz frequency response
  - 170/200 µs rise/fall times, 10-90%

Iris AO, Inc.

Smart Driver II Electronics

128 Channels

512 Channels

- High resolution
  - 14 bit, 200 V
- Low Noise
  - < 4mV *rms*
- Factory calibrated

- Simple USB interface (150 Hz frame rate)
  - Scales to > 10k channels
- High-speed interface (6 kHz frame rate)
  - Scalable to > 4k channels
- Frame rates of 35 kHz supported
  - Direct drive with LVDS

Closed-Loop Flattened DM

Veeco

Mag: 1.4 X
Mode: PSI

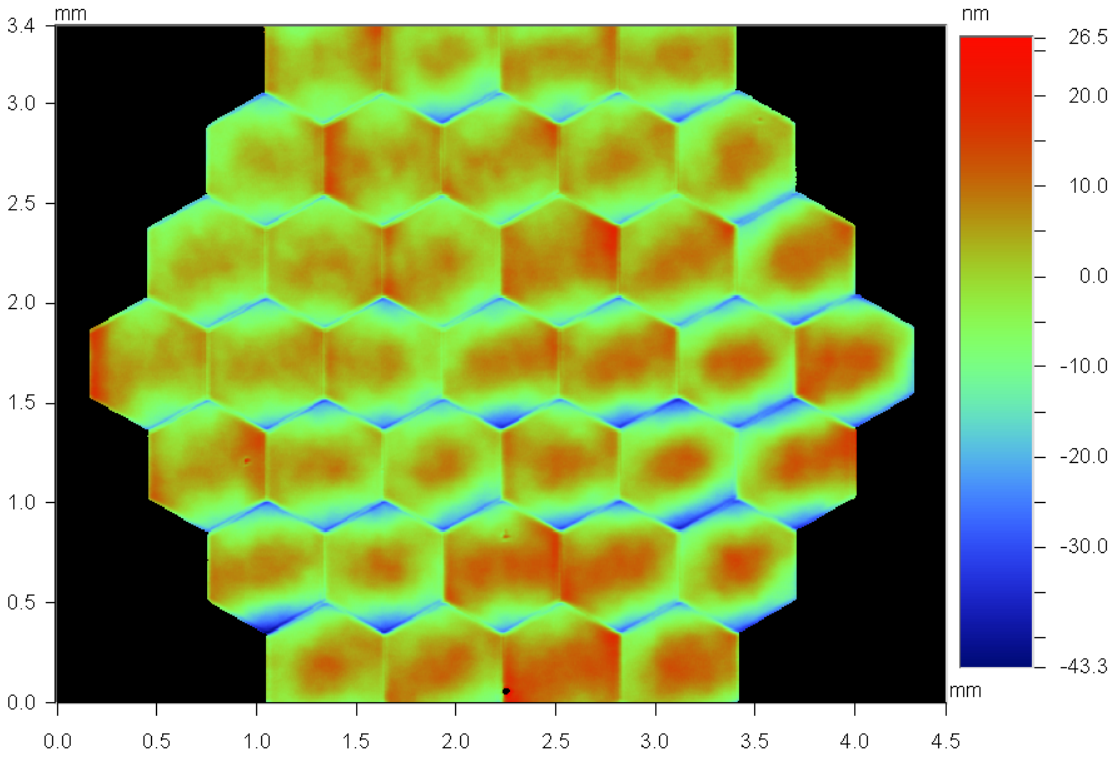
Surface Data

Date: 06/20/2008
Time: 16:19:29

Surface Statistics:
Ra: 6.04 nm
Rq: 7.74 nm
Rz: 55.73 nm
Rt: 69.79 nm

Set-up Parameters:
Size: 736 X 480
Sampling: 6.06 um

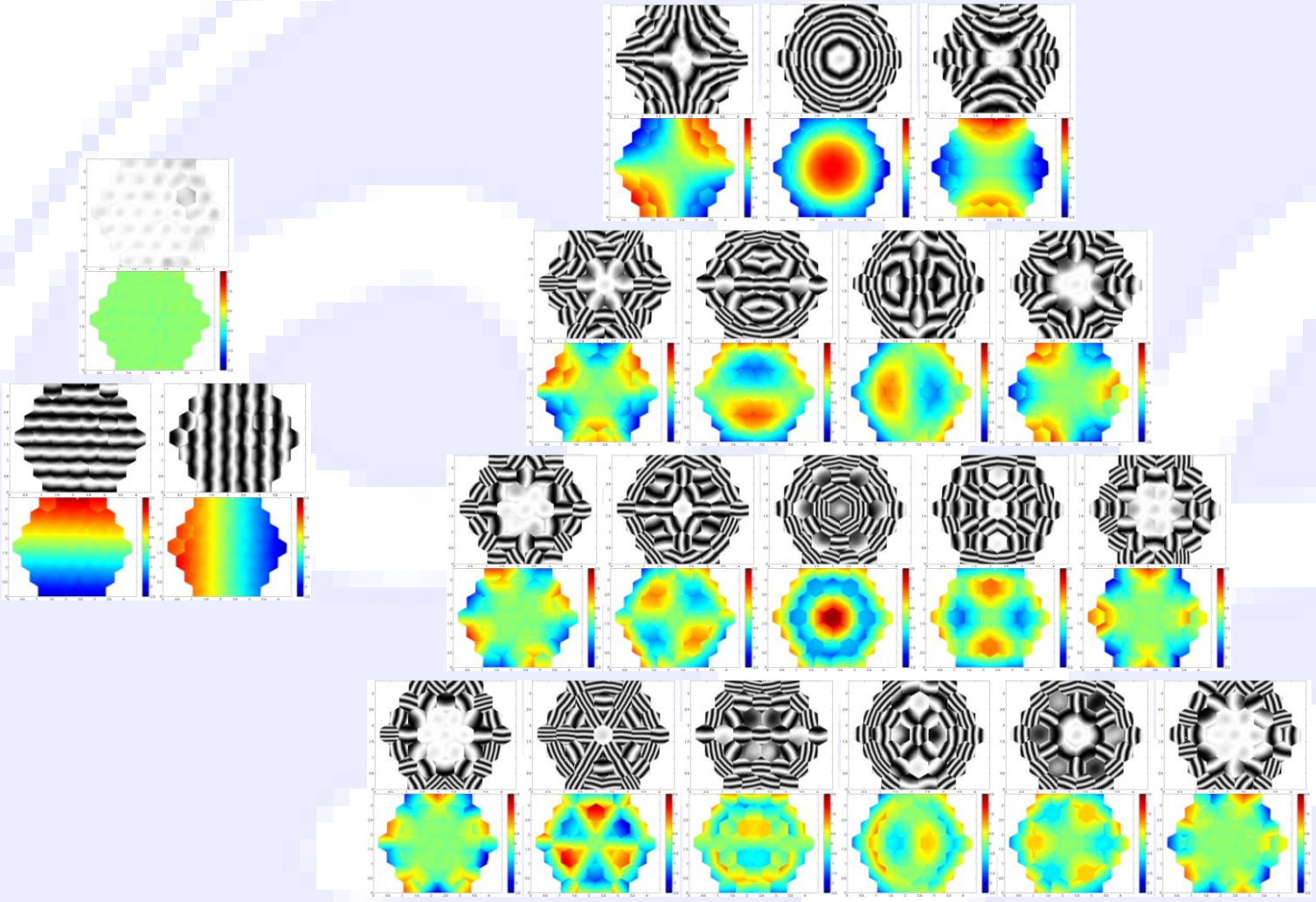
Processed Options:
Terms Removed:
Tilt
Filtering:
None



Title: FSC37-01-07-0614
Note: Closed-Loop Flattened

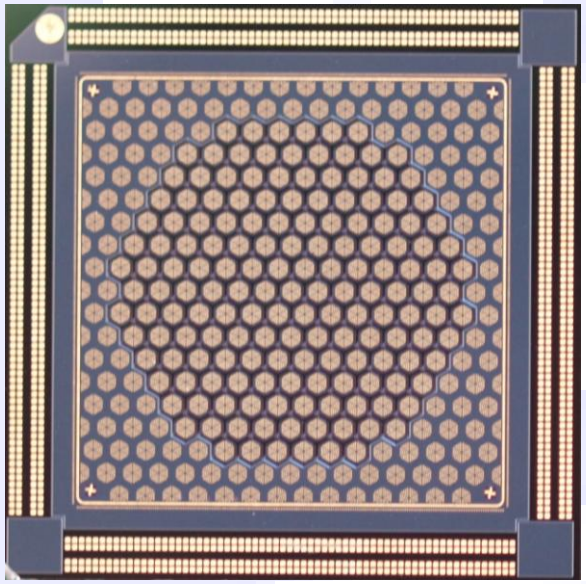
We expect 1-3 nm rms end of June 2009

Factory Calibration: *Open-Loop Positioning Capability*



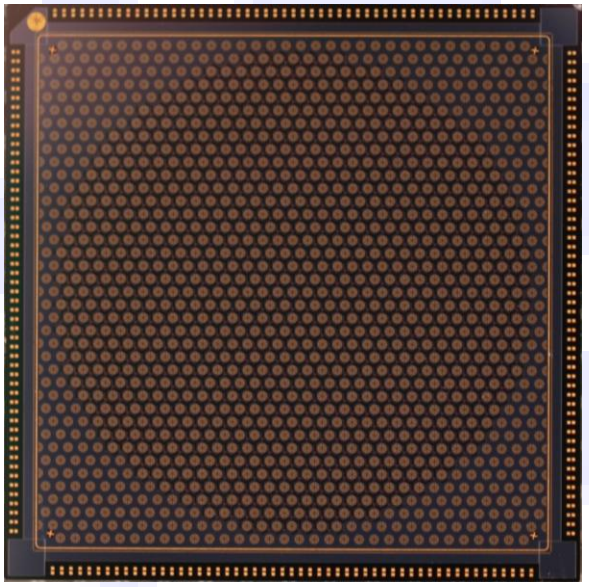
Scaling up, step by step

S163-X Actuator Chip



13.4 mm

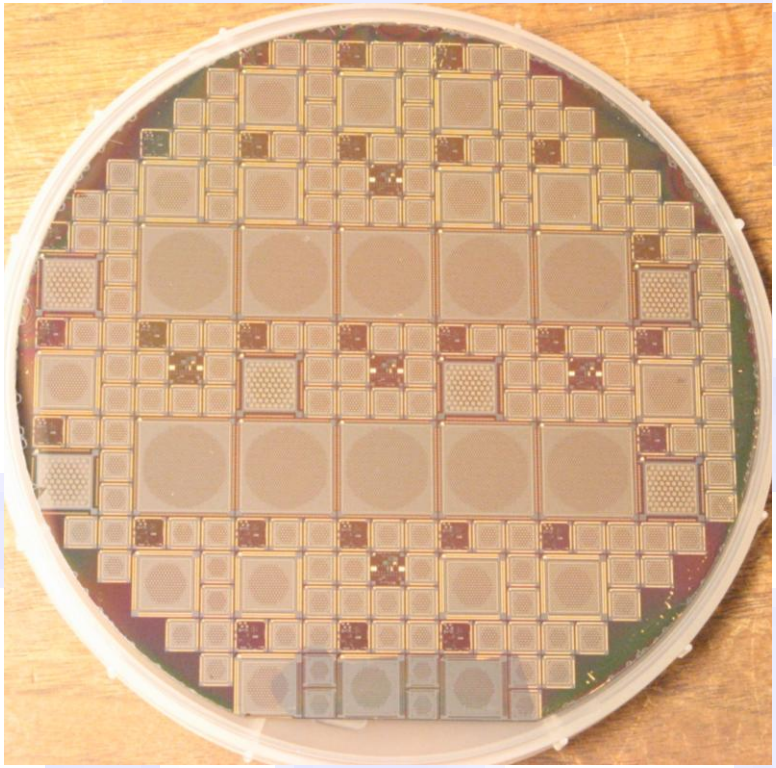
925 Segment Path Finder



20.088 mm

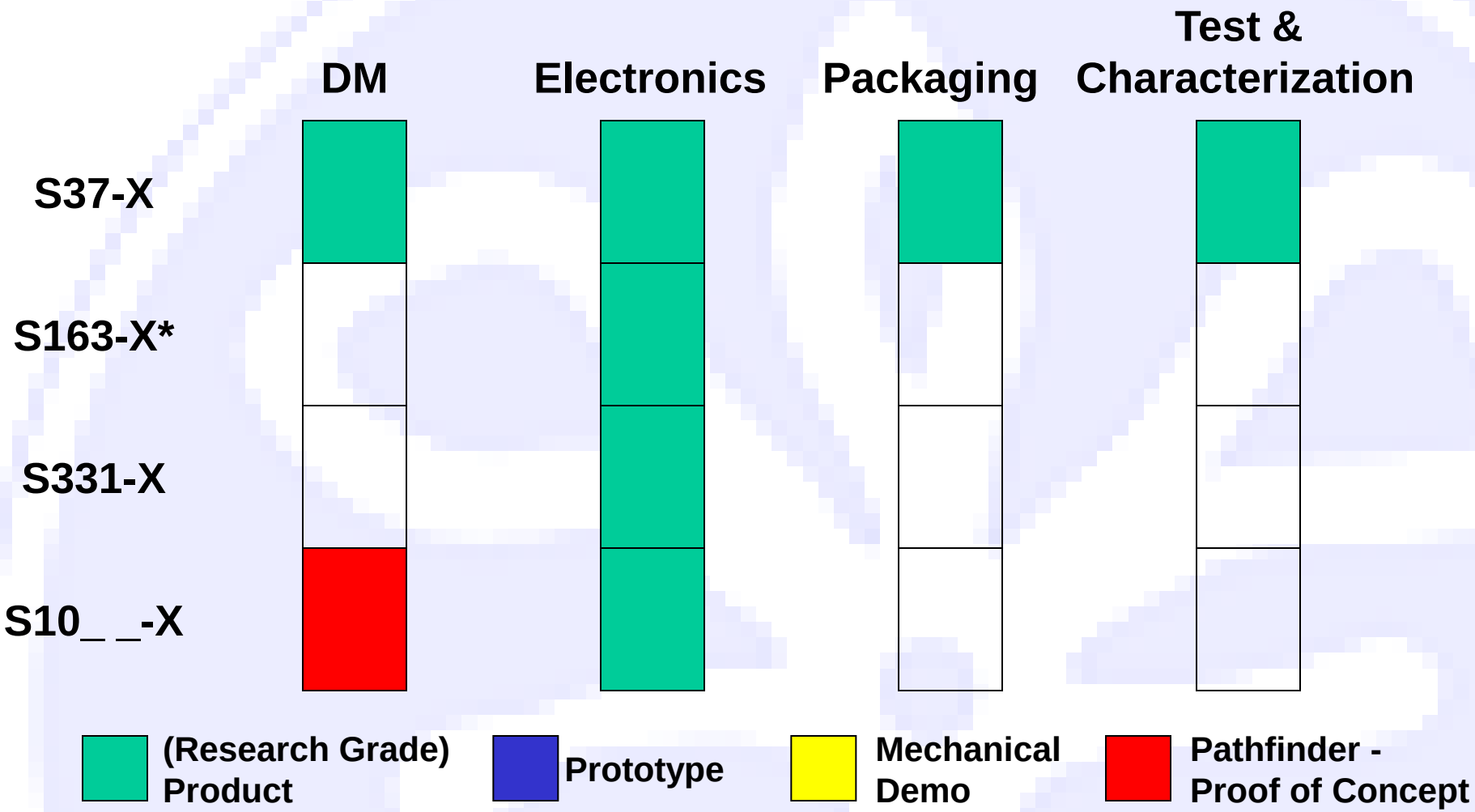
High-Cost MEMS Development with SBIR Funding

- MEMS has high development costs
- Leverage multiple SBIRs from various agencies
  - Multiple projects per wafer
- Develop DM by fabricating in house
  - Better control
  - Less mistakes
  - Greater flexibility
  - Dramatically lower development costs
  - No risk of getting dumped on prom night



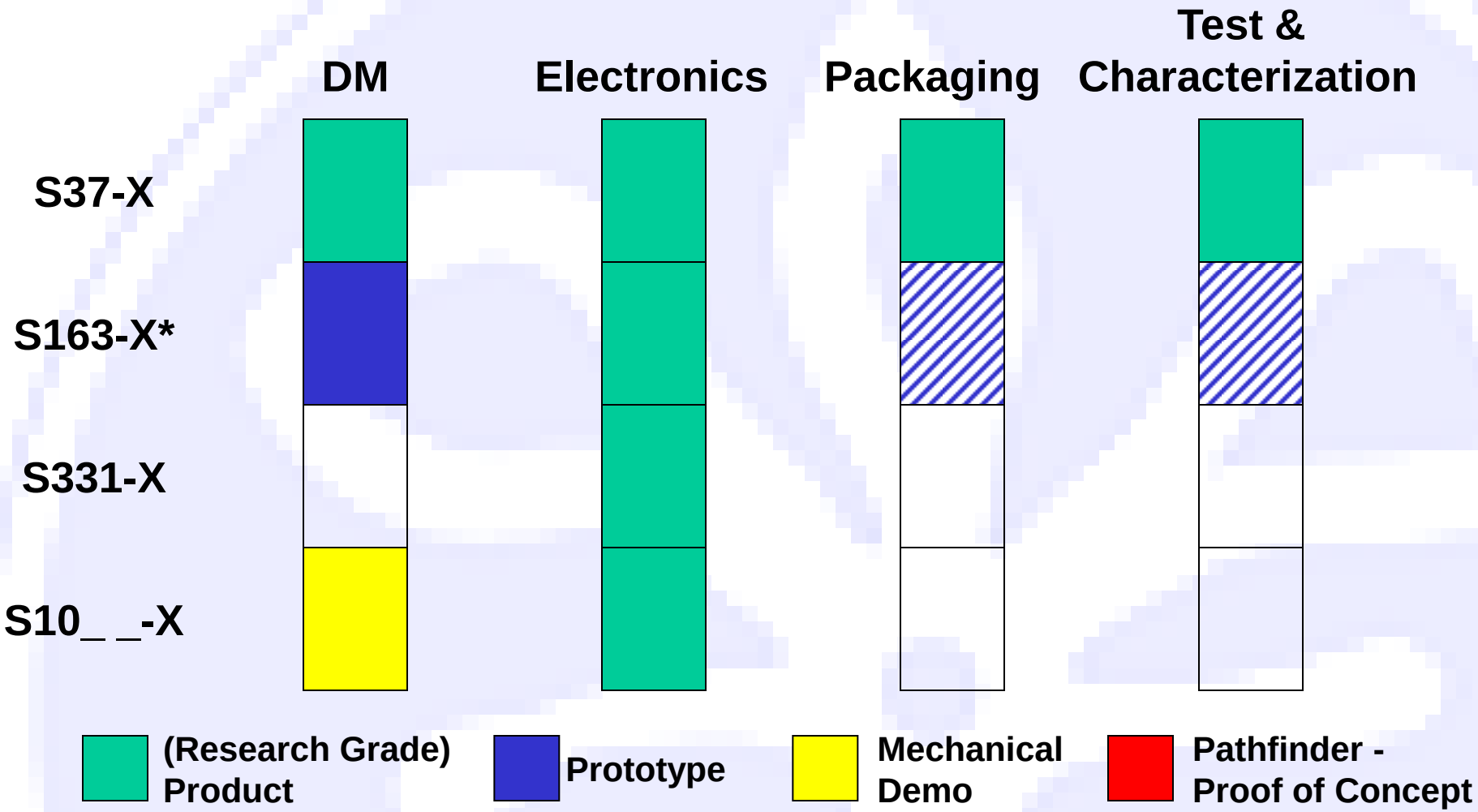
Multi-project 6” Wafer
NIH & NASA SBIRs

DM Development – Pre NASA I (Jan 09)



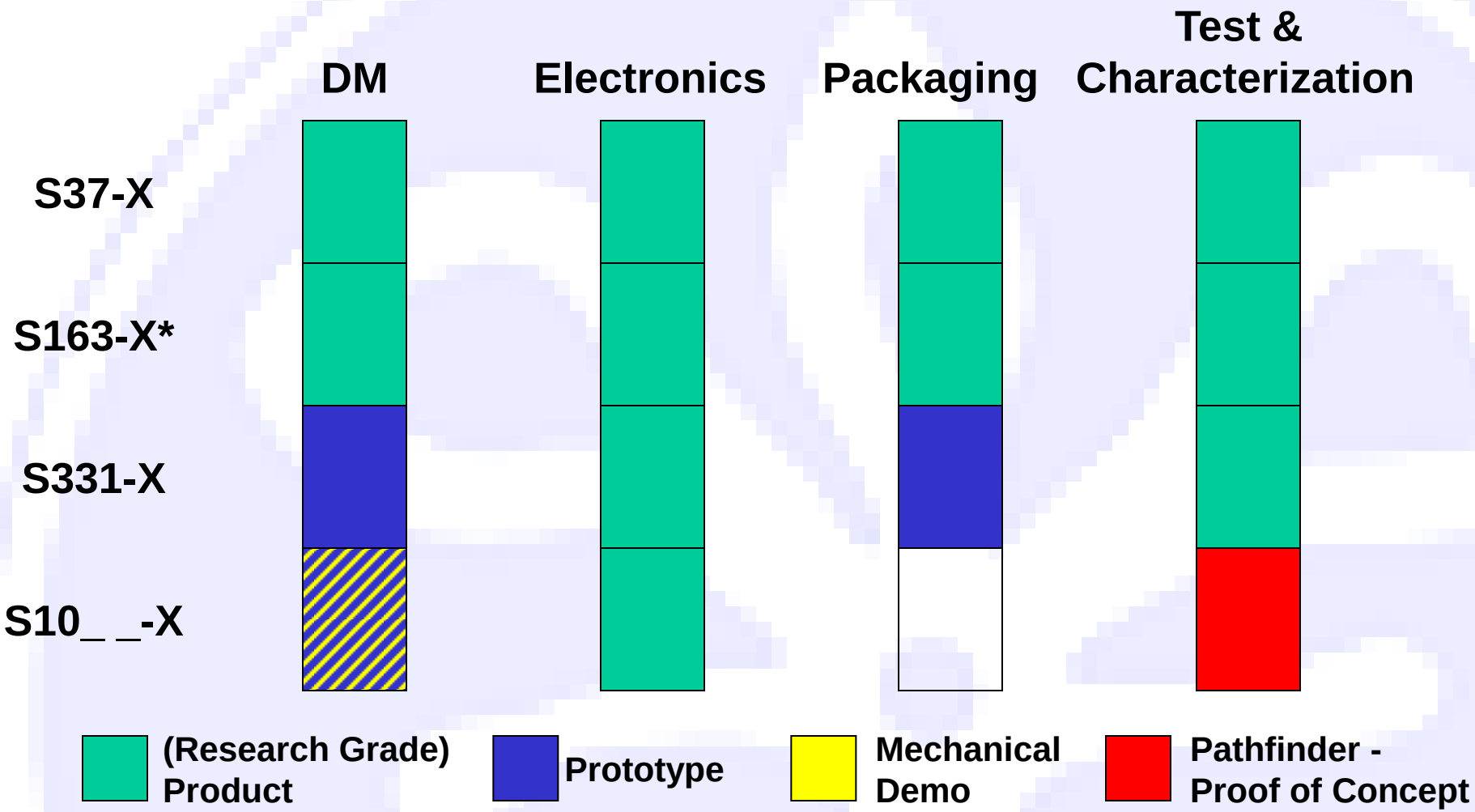
* Funding by the NIH/NEI

DM Development – Post NASA I (July 09)



* Funding by the NIH/NEI

DM Development – Post NASA II (If Awarded)



*** Funding by the NIH/NEI**

Phase I Progress

- Electrical yield of actuator wafers determined
  - >98% for FIRST process run of wired design
    - S37-X actuators as test coupons
    - Failures believed to be pinholes in a thin passivation layer
  - Wafers fabricated in-house
- Actuator wafer (6”) bow reduced ~3.5X (-13.2 µm to 3.5 µm)
  - Achieved by better stress matching
- DMs tested for leakage currents under vacuum
  - No noticeable change
  - Measured down to 10’s pA
- Mirror-wafer layout and fabrication started
  - ~50% completed

Some challenges for 10^3 Segment DMs

- Managing 3000 interconnects
  - Need ***reliable*** and small form factor cabling that can handle 200 V
  - Ceramic IC packaging and wirebonding supports 3000 segments with existing technology
- Chip flatness after release and packaging
  - Ceramic PGA packages can easily have 50µm/25mm camber (saddle shape)
  - Chips flat prior to release will bow after removing sacrificial layers
    - Better stress matching after release
    - Thicker substrates (e.g. 1 mm instead of 625 µm)
- Chip yield scales horribly: $\text{Segment\_Yield}^{\text{num segments}}$
  - Tighter wiring pitch may result in reduced electrical yield
    - Will determine if the yield is reduced because of breakdown
  - Track down failure modes systematically
    - requires extensive testing

Summary

- S37-X DM is a solid foundation from which to scale
- Leveraging different SBIRs will allow Iris AO to methodically scale up segment count
- Promising Phase I preliminary results
  - Good electrical yield for first fabrication run
  - Reduced wafer bow
  - Vacuum operation verified
- Lots of fun challenges for 10^3 segment DMs
  - Solvable engineering problems

Acknowledgements

Funding Sources

- NASA – Phase II SBIR, (Extreme Precision DM Testing and Development)
  - NNG07CA06C
- Center for Adaptive Optics (DM Process Development)
  - National Science Foundation Science and Technology: No. AST – 9876783
- National Eye Institute – Phase II SBIR (DM Process Development)
  - 2 R44 EY015381-02A1
- US Air Force – Phase II SBIR (DM Control)
  - FA8650-04-M-6518
- National Science Foundation – Phase II SBIR (Ancillary Process Development)
  - DMI-0522321

R&D Fabrication Facility

- Berkeley Microfabrication Laboratory

Research Collaboration

- Berkeley Sensor & Actuator Center